

## Claims

1. A method for the production of a spherical or grain-shaped semiconductor element (11) for use in a solar cell, characterized by the following steps:
  - application of a conductive back contact layer (30) onto a spherical or grain-shaped substrate core (20);
  - application of a first precursor layer (40) made of copper or copper gallium;
  - application of a second precursor layer (50) made of indium;
  - reaction of the precursor layers (40) and (50) with sulfur and/or selenium to form a I-III-VI compound semiconductor.
2. The method according to claim 1, characterized in that the main constituent of the conductive back contact layer (30) is molybdenum.
3. The method according to claim 2, characterized in that the conductive back contact layer (30) contains up to 20% by weight of gallium in order to improve the adhesion.
4. The method according to one or more of the preceding claims, characterized in that the layers (30; 40; 50) are each applied by means of PVD and/or CVD methods.

5. The method according to one or more of the preceding claims, characterized in that a layer structure (10) comprising precursor layers (40; 50) is alloyed prior to the reaction to form a I-III-VI compound semiconductor.
6. The method according to claim 5, characterized in that a layer structure (10) comprising precursor layers (40; 50) is alloyed at a temperature of  $T > 220^{\circ}\text{C}$  [ $> 428^{\circ}\text{F}$ ] prior to the reaction to form a I-III-VI compound semiconductor.
7. The method according to one or more of the preceding claims, characterized in that the reaction of the layer structure (10) comprising precursor layers (40; 50) to form a I-III-VI compound semiconductor is carried out in vapor of the reaction element sulfur and/or selenium.
8. The method according to claim 7, characterized in that the reaction of the layer structure (10) is carried out under atmospheric pressure.
9. The method according to claim 7, characterized in that the reaction of the layer structure (10) is carried out in a vacuum.
10. The method according to one or more of the preceding claims, characterized in that the reaction of the layer structure (10) comprising precursor layers (40; 50) to form a I-III-VI compound semiconductor is carried out in a melt of the reaction element sulfur and/or selenium.

11. The method according to one or more of the preceding claims, characterized in that the reaction of the layer structure (10) comprising precursor layers (40; 50) to form a I-III-VI compound semiconductor is carried out in a salt melt with admixtures of the reaction element sulfur and/or selenium.

12. The method according to one or more of the preceding claims, characterized in that the reaction of the layer structure (10) comprising precursor layers (40; 50) to form a I-III-VI compound semiconductor is carried out in hydrogen compounds of the reaction element sulfur and/or selenium.

13. The method according to claim 12, characterized in that the reaction of the layer structure (10) is carried out at atmospheric pressure.

14. The method according to claim 12, characterized in that the reaction of the layer structure (10) is carried out at a pressure lower than atmospheric pressure.

15. The method according to one or more of the preceding claims, characterized in that a treatment with a KCN solution is carried out after the reaction of the layer structure (10) to form a I-III-VI compound semiconductor.

16. The method according to one or more of the preceding claims, characterized in that a buffer layer is deposited after the reaction of the layer structure (10) to form a I-III-VI compound semiconductor.

17. The method according to one or more of the preceding claims, characterized in that a high-resistance ZnO layer is deposited after the reaction of the layer structure (10) to form a I-III-VI compound semiconductor.
18. The method according to claim 17, characterized in that a low-resistance ZnO layer is deposited after the high-resistance ZnO layer.
19. The method according to one or more of claims 16 to 18, characterized in that the layer is deposited by means of PVD or CVD methods.
20. The method according to claim 19, characterized in that the layer is deposited by means of chemical bath deposition.
21. A spherical or grain-shaped semiconductor element for use in solar cells, characterized in that the semiconductor element (11) has a spherical or grain-shaped substrate core (20) that is coated at least with one back contact layer (30) and with one I-III-VI compound semiconductor.
22. The semiconductor element according to claim 21, characterized in that the substrate core (20) consists of glass, metal or ceramics.
23. The semiconductor element according to claim 22, characterized in that the substrate core (20) consists of soda-lime glass.

24. The semiconductor element according to one or more of claims 21 to 23, characterized in that the diameter of the substrate core (20) is in the order of magnitude of 0.1 mm to 1 mm, especially approximately 0.2 mm.

25. The semiconductor element according to one or more of claims 21 to 24, characterized in that the thickness of the back contact layer (30) is in the order of magnitude of 0.1  $\mu\text{m}$  to 1  $\mu\text{m}$ .

26. The semiconductor element according to one or more of claims 21 to 25, characterized in that main constituent of the back contact layer (30) is molybdenum.

27. The semiconductor element according to one or more of claims 21 to 26, characterized in that the back contact layer (30) contains up to 20% by weight of gallium in order to improve the adhesion.

28. The semiconductor element according to one or more of claims 21 to 27, characterized in that the I-III-VI compound semiconductor layer (60) consists of a compound from the group of the copper indium sulfides, copper indium diselenides, copper indium gallium sulfides or copper indium gallium diselenides.

29. The semiconductor element according to one or more of claims 21 to 28, characterized in that the thickness of the I-III-VI compound semiconductor layer (60) is in the order of magnitude of 1  $\mu\text{m}$  to 3  $\mu\text{m}$ .

30. The semiconductor element according to one or more of claims 21 to 29, characterized in that the semiconductor element (11) has a buffer layer above the I-III-VI compound semiconductor layer (60).

31. The semiconductor element according to claim 30, characterized in that the buffer layer consists of a material from the group comprising CdS, ZnS, ZnSe, ZnO, indium selenium compounds or indium sulfur compounds.

32. The semiconductor element according to one or both of claims 30 and 31, characterized in that the thickness of the buffer layer is in the order of magnitude of 20 nm to 200 nm.

33. The semiconductor element according to one or more of claims 21 to 32, characterized in that the semiconductor element has a high-resistance and a low-resistance ZnO layer above the I-III-VI compound semiconductor layer (60).

34. The semiconductor element according to claim 33, characterized in that the thickness of the high-resistance layer is in the order of magnitude of 10 nm to 100 nm.

35. The semiconductor element according to one or both of claims 33 and 34, characterized in that the thickness of the low-resistance ZnO layer is in the order of magnitude of 0.1  $\mu\text{m}$  to 2  $\mu\text{m}$ .

36. The semiconductor element according to one or more of claims 21 to 35, characterized in that the semiconductor element (11) was produced by a method according to one or more of claims 1 to 20.

37. A method for the production of a solar cell having integrated spherical or grain-shaped semiconductor elements, characterized by the following features:

- incorporation of several spherical or grain-shaped semiconductor elements (11) into an insulating support layer (70), whereby the semiconductor elements (11) protrude from the surface of the support layer on at least one side of the support layer, and the semiconductor elements (11) each consist of a spherical or grain-shaped substrate core (20) that is coated at least with one conductive back contact layer (30) and with one I-III-VI compound semiconductor layer (60);
- removal of parts of the semiconductor elements (11) on one side of the support layer (10) so that a surface of the conductive back contact layer (30) of the semiconductor elements (11) is exposed;
- application of a back contact layer (80) onto the side of the support layer (10) on which parts of the semiconductor elements (11) have been removed; and
- application of a front contact layer (90) onto the side of the support layer (10) on which no semiconductor elements (11) have been removed.

38. The method according to claim 37, characterized in that, in addition to parts of the semiconductor elements (11), part of the support layer (10) is also removed.

39. The method according to one or both of claims 37 and 38, characterized in that other function layers are deposited in addition to the front contact layer (40) and the back contact layer (50).

40. The method according to one or more of claims 37 to 39, characterized in that the semiconductor elements (11) are applied onto the support layer (70) by means of scattering, dusting and/or printing and they are subsequently incorporated into the support layer.

41. The method according to one or more of claims 37 to 40, characterized in that the support layer (70) is configured as a matrix with recesses into which the semiconductor elements (11) are incorporated.

42. The method according to one or more of claims 37 to 41, characterized in that the semiconductor elements (11) are incorporated into the support layer (70) by means of a heating and/or pressing procedure.

43. The method according to one or more of claims 37 to 42, characterized in that the removal of the semiconductor elements (11) and/or of the support layer (70) is done by grinding, polishing, etching, thermal energy input and/or by photolithographic processes.

44. The method according to one or more of claims 37 to 43, characterized in that the back contact layer (80) and/or the front contact layer (90) are deposited by



PVD or CVD methods or by other methods adapted to the material of the layer in question.

45. A solar cell having integrated spherical or grain-shaped semiconductor elements, characterized in that the solar cell has at least the following features:

- an insulating support layer (70) into which the spherical or grain-shaped semiconductor elements (11) are incorporated, whereby the semiconductor elements (11) protrude from the layer on at least one side of the support layer (70), and the semiconductor elements (11) each consist of a spherical or grain-shaped substrate core (20) that is coated at least with one conductive back contact layer (30) and with one I-III-VI compound semiconductor layer;
- a back contact layer (80) on one side of the support layer (10), whereby several semiconductor elements (11) on this side of the support layer have a surface that is free of I-III-VI compound semiconductors; and
- a front contact layer (90) on the side of the support layer (70) on which the semiconductor elements (11) do not have a surface that is free of I-III-VI compound semiconductors.

46. The solar cell according to claim 45, characterized in that it is produced by means of a method according to one or more of claims 37 to 44.

47. The solar cell according to one or both of claims 45 and 46, characterized in that the insulating support layer (70) consists of a thermoplastic material.

48. The solar cell according to one or more of the preceding claims 45 to 47, characterized in that the support layer (10) consists of a polymer from the group of the epoxides, polycarbonates, polyesters, polyurethanes, polyacrylics and/or polyimides.

49. The solar cell according to one or more of the preceding claims 45 to 48, characterized in that the spherical or grain-shaped semiconductor elements (11) are semiconductor elements according to one or more of claims 21 to 36.

50. The solar cell according to one or more of claims 45 to 49, characterized in that the semiconductor elements (11) are coated with a I-III-VI compound semiconductor from the group of the copper indium diselenides, copper indium disulfides, copper indium gallium diselenides and copper indium gallium diselenide disulfides.

51. The solar cell according to one or more of claims 45 to 50, characterized in that the front contact layer (90) consists of a conductive material.

52. The solar cell according to claim 51, characterized in that the front contact layer (90) consists of a transparent conductive oxide (TCO).

53. The solar cell according to one or more of claims 45 to 52, characterized in that the back contact layer (80) consists of a conductive material.

54. The solar cell according to claim 53, characterized in that the back contact layer (80) consists of a metal, a transparent conductive oxide (TCO) or a polymer having conductive particles.

55. The solar cell according to claim 54, characterized in that the back contact layer (80) consists of a polymer from the group of the epoxy resins, polyurethanes and/or polyimides having conductive particles from a group comprising carbon, indium, nickel, molybdenum, iron, nickel chromium, silver, aluminum and/or the corresponding alloys or oxides.

56. The solar cell according to claim 53, characterized in that the back contact layer (80) consists of an intrinsic conductive polymer.

57. The solar cell according to claim 56, characterized in that the back contact layer (80) consists of a polymer from the group of the PANis.

58. The solar cell according to one or more of claims 45 to 57, characterized in that the solar cell has other function layers in addition to the front contact layer (90) and the back contact layer (80).

59. A photovoltaic module, characterized in that it has at least one solar cell according to one or more of claims 45 to 58.